



Barcode No. 1900162841



Do not write/Mark on Bar Code

## Supplement Booklet Information

Supplement Taken	Write the Supplement Barcode No.
(Y) ●	
If Yes, How Many Booklets	
(1) (2) (3) (4)	
Confirm and Sign by Block Supervisor	

11.12.19

(Read the Instructions given on the reverse side)

Use Blue/Black Ball Pen only to darken the appropriate circles. Do not fold, tear, wrinkle, staple or use whitener on the cover page of the answer book. Do not write or mark on the barcode and the timing tracks.

CORRECT METHOD



WRONG METHOD



Signature of Candidate	Candidate Seat Number
	20192192
College Seal and Date	
DEC 2019	
Medium of Answer	
1. English ●	
2. Marathi ○	
3. Other ○	
PRN	2019001698
Candidate Seat No.	20192192

Q.P.Code	Subject Code (printed on Hallticket)
034147	031064
●○○○○○○○	●○○●○○○
①①①●①①	①①●①①①
②②②②②②	②②②②②②
③●③③③③	③●③③③③
④④●④●④	④④④④④●
⑤⑤⑤⑤⑤⑤	⑤⑤⑤⑤⑤⑤
⑥⑥⑥⑥⑥⑥	⑥⑥⑥⑥●⑥
⑦⑦⑦⑦⑦●	⑦⑦⑦⑦⑦⑦
⑧⑧⑧⑧⑧⑧	⑧⑧⑧⑧⑧⑧
⑨⑨⑨⑨⑨⑨	⑨⑨⑨⑨⑨⑨
Signature & Name of the Block Supervisor with Date	Signature of Chief Coordinator
11.12.19	

Exam Date	11	12	2019
Program Name			
Program Code	Year	Semester	
	2019	000I	
Subject Name	Quantum Mechanics		
Subject Code	031064		

## Part - B

Barcode No. 1900162841



Do not write/Mark on Bar Code

Question wise marks given by Examiner			
Q. No.	Marks	Q. No.	Marks
1		6	
2		7	
3		8	
4		9	
5		10	
		Total	
Name and Signature of Examiner with Date			

Exam Date	11/12/2019
Program Code & Name	
Subject Code & Name	31064 & Quantum Mechanics
Year / Semester	2019 / Semester I

If Physically challenged : LD ○ PC ○ VI ○ Regular ●

Question wise marks given by Moderator			
Q. No.	Marks	Q. No.	Marks
1		6	
2		7	
3		8	
4		9	
5		10	
		Total	
Name and Signature of Moderator with Date			

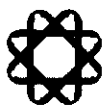
## **INSTRUCTIONS TO CANDIDATES**

1. Candidates should occupy the correct seat and write correct seat number and other details in the space provided for the purpose on the answer-books.
2. Candidates who are not in their seats by the time notified, will not as a rule be permitted to appear for the examination. The Senior Supervisor may at his/her discretion admit those who give him/her a satisfactory reason.
3. Each answer-book contains forty pages. Check whether the pages are properly numbered.
4. Candidates should write their answers in legible handwriting. They are warned that zero marks may be assigned to answers which cannot be assessed by the examiners owing to illegible handwriting.
5. Write on both sides of a page. Rough work where necessary, should be done on the last page in the space provided. No page should be left blank. Any such act shall be treated as unfair means.
6. Do not write anything in the Examiner & Moderator sheet (Part-B) & Re-Evaluator Sheet except Candidate details.
7. Do not damage or make any stray marks on the barcodes.
8. Candidates will not be permitted to leave the examination hall until half an hour after the question paper is distributed.
9. All answer-books supplied shall be returned whether written or blank. Nothing shall be written on the question-paper.
10. No sheet shall be torn from the provided answer-books nor shall additional papers attached to them.
11. Even if it is mentioned in question paper to write each section in separate answer book, if any paper / subject have multiple sections, the candidate has to write all sections in one and the same answer book.
12. A warning bell will be given ten minutes before the close of the examination. Candidates will not be allowed to leave the examination hall during the last ten minutes. At the final bell, they must stop writing and be ready to hand over their answer books to the Junior Supervisor. They should not leave their seats until answer-books from all candidates are collected by the Junior Supervisor.

## **UNFAIR MEANS IN THE EXAMINATIONS**

13. **Candidates shall write the answers only with BLUE/BLACK ink Ball pen only. Use of any other Pen like Gel ink or Fountain ink or any other colour ink, will be treated as unfair means in terms of revealing of identity.**
14. **Candidates are forbidden to (i) bring any book, notes, scribbling papers, pages, Mobile phones/smart watches or any other similar devices. (ii) speak or communicate in any manner to any other candidate, while the examination is in progress, and (iii) take with them any answer-book written or blank while leaving the examination hall. The supervisors/authorized persons are authorized to check the students.**
15. A candidate who disobeys any instructions issued by the Senior/ Junior Supervisor or who is guilty of rude or disobedient behavior is liable for disciplinary action to be taken against him / her by the University.
16. Do not fold the answer book anywhere because it will be treated as unfair means in terms of revealing of identity.
17. Candidates suspected to be guilty of any of the aforesaid acts will be allowed to write their paper only after giving an undertaking in writing that the decision of the University in respect of the reported act of unfair means is binding on them/Exchange of writing materials, stencils, mathematical instruments, etc. is strictly prohibited. If candidates want anything, they should approach the Junior Supervisor without disturbing other candidates. However, they should not leave their seats on any account..
18. Any method to bribe the examiner/s by attaching currency notes or letters is strictly prohibited and will result in serious action being taken by the University
19. **Seat number should be written only the space provided for the same. Candidate should not write his/her name in any part of the answer-book. Writing Name, Seat No., Phone/Cell No., putting signature, use of religious invocation or any writing that is not relevant to the answers anywhere in the answer-book will be treated as attempts to reveal identity.**
20. Underlining of answers for focusing attention is permitted. However, use of varied inks, except for illustrations and figures must be avoided. DO NOT use symbol like encircling the question or using colour arrows for P.T.O. These will all be considered as attempt to readily identify the specific answer-book & will be treated as unfair means.

**IT IS PRESUMED THAT CANDIDATE HAS READ ALL THE ABOVE INSTRUCTIONS.**



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Q1

$$b) \{|\phi_1\rangle, |\phi_2\rangle, |\phi_3\rangle\} \quad \text{--- (1)}$$

The vectors  $|\psi_0\rangle$  and  $|\psi_1\rangle$  are defined

$$|\psi_0\rangle = \frac{1}{\sqrt{2}} |\phi_1\rangle + \frac{i}{2} |\phi_2\rangle + \frac{1}{2} |\phi_3\rangle \quad \text{--- (2)}$$

$$\langle \psi_0 | = \frac{1}{\sqrt{2}} \langle \phi_1 | + \frac{i}{2} \langle \phi_2 | + \frac{1}{2} \langle \phi_3 |$$

$$|\psi_1\rangle = \frac{1}{\sqrt{3}} |\phi_1\rangle + \frac{i}{\sqrt{3}} |\phi_3\rangle \quad \text{--- (3)}$$

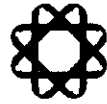
$$\langle \psi_0 | = \frac{1}{\sqrt{2}} \langle \phi_1 | + \frac{i}{2} \langle \phi_2 | + \frac{1}{2} \langle \phi_3 | \quad \text{--- (4)}$$

$$\langle \psi_1 | = \frac{1}{\sqrt{3}} \langle \phi_1 | + \frac{i}{\sqrt{3}} \langle \phi_3 | \quad \text{--- (5)}$$

$$\langle \psi_0 | \psi_1 \rangle = 0$$

$$\left[ \frac{1}{\sqrt{2}} \langle \phi_1 | + \frac{i}{2} \langle \phi_2 | + \frac{1}{2} \langle \phi_3 | \right]$$

$$\left[ \frac{1}{\sqrt{3}} |\phi_1\rangle + \frac{i}{\sqrt{3}} \langle \phi_3 | \right]$$



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$$\text{or } \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{3}} \times \frac{i}{2} + \frac{1}{2} \times \frac{1}{\sqrt{3}}$$

$$\frac{1}{\sqrt{3}} \times \frac{1}{2} + \frac{1}{2\sqrt{3}}$$

$$= \frac{1}{4\sqrt{3}}$$

$$\langle \psi, \psi_0 \rangle =$$

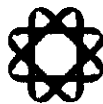
$$\left[ \frac{1}{\sqrt{3}} \langle \phi_1 + \frac{i}{\sqrt{3}} \langle \phi_3 \rangle + \right.$$

$$\left. \left[ \frac{1}{\sqrt{3}} \langle \phi_1 \rangle + \frac{i}{\sqrt{3}} \langle \phi_2 \rangle \right] \right]$$

$$\frac{1}{\sqrt{3}} \times \frac{1}{\sqrt{2}} + \frac{1}{2} + \frac{i}{\sqrt{3}} \times \frac{1}{2}$$

$$= \frac{1}{\sqrt{5}} + \frac{1}{2\sqrt{3}} + \frac{1}{2}$$

$$= \frac{1}{4\sqrt{5}}$$



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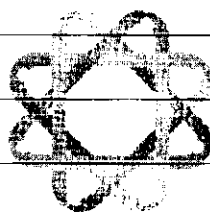
Q1

a.

Postulates of quantum mechanics.

Quantum no. ~~There are number 4~~There are 4 quantum numbers  
principle quantum number, magnetic  
quantum no. Angular spin no.According to Pauli Exclusive principle  
no. of quantum no. of an electron can  
be identical.In. This quantum no. have the all the  
measurable values of a wave function  
This wave function can be denoted  
by  $\psi$ .

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Q2

c. Eigen values of  $L_z$  is  $m\hbar$ -

$$H\psi = E\psi$$

$$L_z \psi = C\psi \quad (1)$$

$$L_z = \frac{\hbar}{i} \frac{\partial}{\partial \phi}$$

$$\frac{\hbar}{i} \frac{\partial}{\partial \phi} \psi = C\psi \quad (2)$$

$$\frac{\partial \psi}{\psi} = \frac{ic}{\hbar} \partial \phi$$

Integrating

$$\int \frac{\partial \psi}{\psi} = \frac{ic}{\hbar} \phi$$

$$\psi = f(r, \theta) e^{ic\phi/\hbar}$$

$$f(r, \theta) = e^{ic\phi/\hbar} (2\pi + \phi)$$

$$f(r, \theta) = e^{ic\phi/\hbar} (e^{i2\pi c/\hbar}) \quad (3)$$

~~f(r, \theta)~~  
wave function does not change.



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$$e^{i2\pi C\hbar} = 1$$

$$e^{i2\pi C\hbar} = e^{2\pi i C\hbar}$$

$$e^{i2\pi C\hbar} =$$

$$\frac{i2\pi C}{\hbar} = 2\pi i n$$

$$C = \hbar n$$

now integrate  
then

$$\boxed{L_z = m\hbar}$$



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Q2

d) Components of arbitrary vectors  $A$  and  $B$  commute with those of  $\sigma$

To prove  $(\sigma \cdot A)(\sigma \cdot B) = A \cdot B + i\sigma \cdot (A \times B)$

$$(\sigma \cdot A) = \sigma_x A_1 + \sigma_y A_2 + \sigma_z A_3$$

$$(\sigma \cdot B) = \sigma_x B_1 + \sigma_y B_2 + \sigma_z B_3$$

$$\sigma = \sigma_x \hat{i} + \sigma_y \hat{j} + \sigma_z \hat{k}$$

$$A = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$$

$$B = B_x \hat{i} + B_y \hat{j} + B_z \hat{k}$$

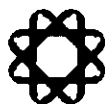
$$(\sigma \cdot A)(\sigma \cdot B) = (\sigma_x A_x + \sigma_y A_y + \sigma_z A_z) + (\sigma_x B_x + \sigma_y B_y + \sigma_z B_z)$$

$$\sigma_x^2 A_x B_x + \sigma_y^2 A_y B_y + \sigma_z^2 A_z B_z$$

$$= \sigma_x^2 A_x B_x + \sigma_x \sigma_y A_x B_y + \sigma_x \sigma_z A_x B_z + \sigma_y \sigma_x A_y B_x + \sigma_y^2 A_y B_y + \sigma_y \sigma_z A_y B_z + \sigma_z \sigma_x A_z B_x + \sigma_z \sigma_y A_z B_y + \sigma_z^2 A_z B_z$$

$$= \sigma_x^2 + \sigma_y^2 + \sigma_z^2 = 1$$

$$= \cancel{\sigma_x} A_x B_x + \sigma_x \sigma_y A_x B_y + \sigma_x \sigma_z A_x B_z + \sigma_y \sigma_x A_y B_x + A_y B_y + \sigma_y \sigma_z A_y B_z + \sigma_z \sigma_x A_z B_x + \sigma_z \sigma_y A_z B_y + A_z B_z$$



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$$\sigma_x \sigma_y = -\sigma_y \sigma_x = i\sigma_z$$

$$\sigma_y \sigma_z = -\sigma_z \sigma_y = i\sigma_x$$

$$\sigma_z \sigma_x = -\sigma_x \sigma_z = i\sigma_y$$

$$= A_x B_x + i\sigma_z A_x B_y - i\sigma_y A_x B_z + i\sigma_z A_y B_x + A_y B_y + i\sigma_x B_y B_z + i\sigma_x A_x B_x - i\sigma_x A_z B_y + A_z B_z.$$

$$A_x B_y + i\sigma_z (A_x B_y + A_x B_y) - \sigma_y (A_x B_z + A_z B_z) + (A_y B_y + i\sigma_x (A_y B_z + A_z B_y)) + A_z B_z$$

$$= A_x B_x + A_y B_y + A_z B_z + i\sigma_x (A_x B_y - A_x B_y) - \sigma_y (A_x B_z) + (A_x B_z + A_z B_y) + A_z B_z$$

$$(A \cdot B) + i\sigma (B \cdot A)$$

Hence

$$(\sigma \cdot A) (\sigma \cdot B) = (A \cdot B) + i\sigma (B \cdot A).$$



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Q3

a) Perturbation theory

$$H^{\lambda} = H^0 + H^{\lambda} \text{ --- (1)}$$

$$\psi_n H^0 = E_n^{(0)} \psi_n^{(0)}$$

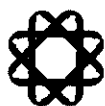
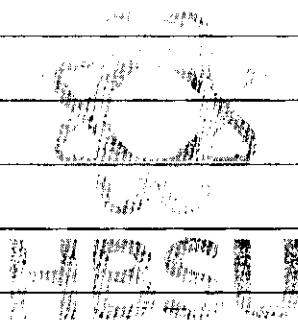
$$H \psi_n^{\lambda} = E_n \psi_n^{\lambda} \text{ --- (2)}$$

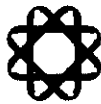
$$\text{Where } E_n = E_n^{(0)} + \lambda E_n^{(1)} + \lambda^2 E_n^{(2)} + \dots$$

$$\psi_n^{\lambda} = \psi_n^{(0)} + \lambda \psi_n^{(1)} + \lambda^2 \psi_n^{(2)} + \dots$$

$$H \psi_n = (E_n + \lambda E_n^{(1)} + \lambda^2 E_n^{(2)} + \dots) (\psi_n^{(0)} + \lambda \psi_n^{(1)} + \lambda^2 \psi_n^{(2)} + \dots)$$

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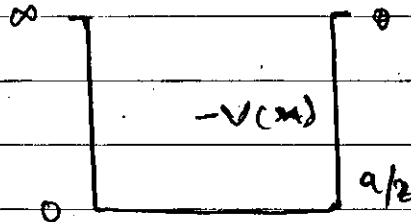


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Q3

b) 1-D box of bottom potential clip

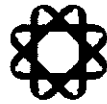


$$\psi = \sqrt{2} \sin\left(\frac{n\pi x}{a}\right) \quad E = \frac{n^2 \pi^2 \hbar^2}{2m a^2}$$

$$\psi = \sqrt{2} \sin\left(\frac{n\pi x}{a}\right)$$

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P.T.O



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$$\int_0^a \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a} |H'| \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a}$$

$$\int_0^a \sqrt{\frac{2}{a}} \sin \frac{n\pi x}{a} [V_0] \sin \sqrt{\frac{2}{a}}$$

$$= V_0 \int \frac{2}{a} \sin 2\pi \frac{x}{a}$$

$$= V_0 \frac{x}{a} \int 1 - \cos \frac{n\pi x}{a}$$

$$= \frac{V_0}{a} x \int_0^a [x] + \int_0^a 1 - \cos 2\pi x$$

$$= \frac{V_0}{a} \left[ \frac{a}{2} \right]$$

$$\boxed{= \frac{V_0}{2}}$$

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85

→ a) Dirac delta function is not the actually mathematical parameter. But the values are given

$$\delta(x) = \begin{cases} 0 & x \neq 0 \\ \infty & x = 0 \end{cases} \quad \text{--- (1)}$$

$$\delta(x - x_0) = \begin{cases} 0 & x \neq x_0 \\ \infty & x = x_0 \end{cases} \quad \text{--- (2)}$$

$$\int_{-\infty}^{\infty} \delta(x) dx = 1 \quad \text{--- (3)}$$

$$\int_{-\infty}^{\infty} \delta(x - x_0) dx = 1 \quad \text{--- (4)}$$

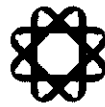
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Properties of Dirac delta function

$$1. \int_{-\infty}^{\infty} \delta(x - x_0) dx = 1$$

$$2. \int_{-\infty}^{\infty} \delta(x - c) dx = 1$$

$$3. \int_{-\infty}^{\infty} \delta(f) \delta(x - c) df = \delta(f)$$



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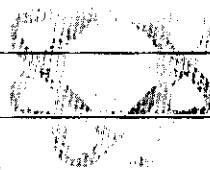
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Q5

b

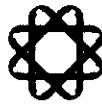
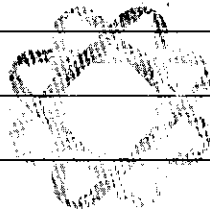
To prove that

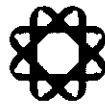
$$e^{\sigma \cdot \hat{n} \theta} = \cos \theta + i \sigma \cdot \hat{n} \sin \theta$$

Where  $\sigma$  is pauli spin matrix. $\hat{n}$  is a unit normal vector.

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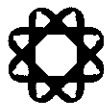
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Q4

d. Elastic scattering:  
The scattering

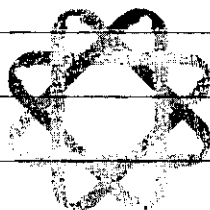
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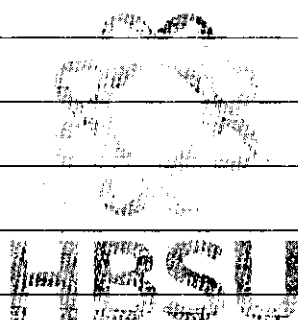
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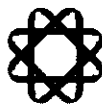
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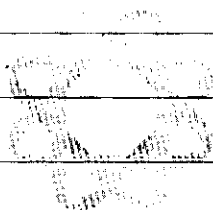
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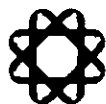
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Condition	10-12 years	13-15 years	16-18 years	19-21 years	22-24 years
1	85	75	65	60	55
2	90	80	70	65	60
3	95	85	75	70	65
4	100	90	80	75	70
5	100	95	85	80	75



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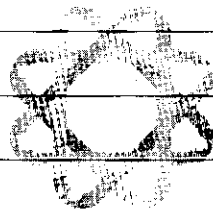
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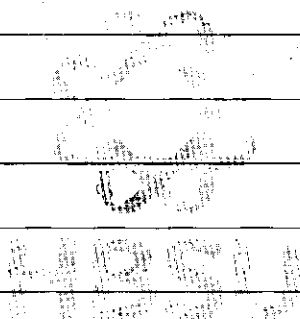


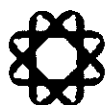
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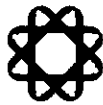




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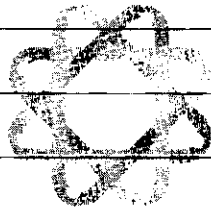


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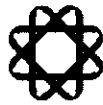
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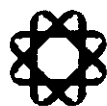
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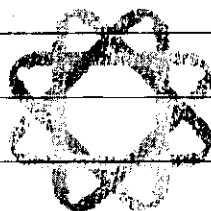


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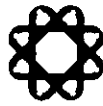
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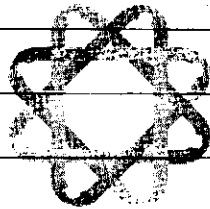


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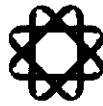


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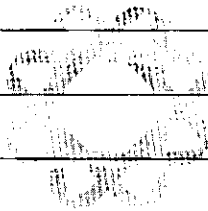
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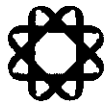
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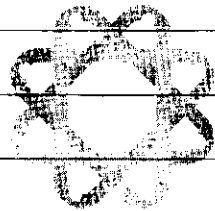
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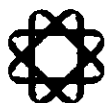


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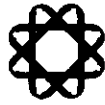
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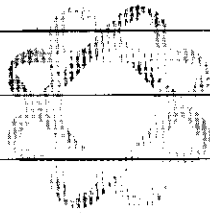
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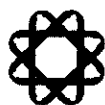
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# Rough Work

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## Re-Evaluator Sheet

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Exam Date : .....

Program Code & Name : .....

Subject Code & Name : .....

Year / Semester : .....

### Questionwise Marks given by Re-Evaluator

Q. No.	Marks	Q. No.	Marks
1		6	
2		7	
3		8	
4		9	
5		10	
		<b>Total</b>	

Name & Signature of Re-Evaluator with Date